billows were floating below us. These, tho wonderfully beautiful, dyed in the rich colors of the declining sun, shut off the greater portion of the island from our view. On my previous visit to Etna, in May, 1884, the atmosphere was much clearer. Then we could see the greater part of the island. The entire east coast was outstretched below us. The billows of the sea breaking upon the rocky coast gave it a silvery edging. Two cities and a vast number of villages and hamlets incrusted the seashore, dotted the valleys, and nestled on the hillside. The Sicilian Mountain chains rose about us in great irregular ridges, crest peeping over crest. Stromboli to the north (seemingly but a stone's throw away), protruded his rocky head and shoulders above the sea. He was throwing a dense column of black smoke thousands of feet into the heavens. Adjacent was the little island volcano throwing upward white puffs of clouds. Mount Etna at the same time was shooting upward an immense column of sulphurous steam, rendering it impossible to see much of the interior of the crater. An inky black cloud hung below us at the west. From it came zig-zag chains of lightning flashes and thunder peals. We looked down upon the storm; it was raining below us, but we were in the sunshine above.

When the heavens are free of clouds the whole island, with its innumerable mountain peaks, is visible from the rim of the crater. With a glass the waves of the sea may be seen breaking in foam upon the rocky coast of the entire island. Malta is visible in the south, Stromboli and the Lipari Islands to the north, the Aegedian Islands to the west, and the three great seas of the Mediterranean—the Ionian, the African, and the Tyrrhian.

The sun was low down in the west and seemed to swim in a sea of glory. A stratus of clouds lay low in the heavens shutting off all view from the west. The stratus did not resemble clouds, but looked like a vast sea flecked with gold by the setting sun. As the sun neared the western horizon, it cast a great purple shadow of Etna against the eastern sky. It was triangular shaped and seemed to hang vertically in the heavens. For a time the rising moon shone with its silver light in the very apex of the purple pyramid. It was the strangest and most beautiful scene my eyes ever beheld.

DUSTFALL IN IDAHO.

Under date of April 18, 1908, Mr. F. Roch, the special observer of Wallace, Idaho, writes:

Twice within the past ten days we have had rainfalls so heavily charged with dust—the dust in dry form falling in flakes the size of a pinhead—that they might be called dustfalls instead of rain. These specks of dust came down as straight as it would be possible for a gentle rain to fall, and the fall continued for several hours intermittently.

This large quantity of dust must have had a special origin nearby and we hope that Mr. Roch will trace it to its source.—EDITOR.

METEOROLOGICAL EDUCATION.

In connection with the statistics of educational work by Weather Bureau officials, the editor would be glad to know of stations at which such work could be done more satisfactorily than now if some one especially fitted as teacher were attached to the local office force. Of course the teaching is only a small part of the official work, but it is well to have it done creditably to the Bureau. The subject is really so important and so interesting that we think colleges and academies will certainly take pride in being pioneers in the work.—EDITOR.

THE LAW OF THE EARTH'S NOCTURNAL COOLING.

By Prof. WILLIAM H. JACKSON. Dated Haverford College, Haverford, Pa., May 13, 1908.

In 1872 A. Weilenmann[1] showed that the normal temperature curve from sunset to sunrise may be represented by a formula appropriate to the Newtonian rate of cooling, that is by

$$\theta = \theta_0 + C\,b^t \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where t denotes the time measured in hours from midnight, θ the temperatures at time t, and θ_0, C, b are constants chosen to fit the observations as well as possible. Further, he found the striking agreement between the values of b for different places, as shown in the following table:

TABLE 1.—*Values of b for different places.*

Place.	Log b.	Duration of observations, in years.
Hobarton	$\bar{1}.934$	8
Berne	$\bar{1}.935$	7
Great St. Bernard	$\bar{1}.936$	19
St. Petersburg	$\bar{1}.938$	16
Ghent	$\bar{1}.939$	24
Prague	$\bar{1}.939$	13
Toronto	$\bar{1}.940$	6
Batavia	$\bar{1}.942$	3

In 1888 M. Alfred Angot[2] found that the corresponding values of log b for St. Maur, near Paris, were $\bar{1}.940$ for clear nights and $\bar{1}.936$ for cloudy nights. This is an independent confirmation of Weilenmann's results, and seems to show what might perhaps be inferred from those previous results, that the value of b is practically independent of the state of the atmosphere.

I was informed of these facts early in 1906, when Prof. Arthur Schuster drew my attention to a paper by Dr. S. Tetsu Tamura,[3] which gives an excellent account of the whole subject. At the same time he suggested that the facts could probably be explained by supposing that the earth radiated like a black body and that the question might be treated as one of heat conduction.

Attempts to treat the matter theoretically only led to two negative conclusions. First: It is unlikely that such a law can represent the actual facts, because such a law implies a solution of the differential equations to be solved of the form

$$\theta = f(x)\,e^{-kt},$$

where x denotes the distance from the surface of the earth. Such a law as this implies that all temperatures are decreasing at the same rate; whereas we know that the relative temperatures of the earth and atmosphere vary considerably in the course of the night. Secondly: If such a law represented the state of affairs, the coefficient b would vary from place to place, according to the nature of the ground.

Or we may look at the question from a purely theoretical point of view. Following Riemann,[4] the solution of the problem of the cooling of a very large conducting sphere, originally everywhere at unit temperature, and radiating heat into space at a rate proportional to the constant h, allows the surface temperature to be exprest by the formula,

$$\theta = 2\pi^{-\frac{1}{2}}\,h e^{a^2h^2t}\int_{a\sqrt{t}}^{\infty} e^{-h^2s^2}\,ds \ldots\ldots\ldots\ldots (2)$$

where a is the diffusivity of the sphere. Extending this formula to the case of a sphere normally in a steady state of heat flow, but which has been subjected to a uniform increase of temperature, and which is then left to return to its original normal condition, we obtain the series,

$$\theta = \theta_0 + \theta'\left(1 - 2\pi^{-\frac{1}{2}}aht^{\frac{1}{2}} + a^2h^2t + \tfrac{2}{3}\pi^{-\frac{1}{2}}a^3h^3t^{\frac{3}{2}} + \ldots\ldots\right) \ldots (3)$$

To obtain a more approximate solution for the actual case of the earth, we should of course suppose that the disturbance from the normal state was not a uniform increase of temperature, but a complicated function, decreasing as the distance below the surface of the earth increases. I have not thought it worth while to attempt this, because as explained, later, I believe the problem is best attacked by other methods.

[1] Ueber den täglichen Gang der Temperatur in Bern. Schweizerische Meteorologische Beobachtungen. Band IX. 1872.

[2] Influence de la Nébulosité sur la variation diurne de la température à Paris. Annales du Bureau Central. 1888.

[3] Mathematical Theory of Nocturnal Cooling of Atmosphere. Monthly Weather Review, April, 1905.

[4] Partielle Differentialgleichungen und deren Anwendung auf physikalische Fragen. Par. 69, 3d Edit. 1882. The same result is obtained by a different method by Carslaw, Fourier's Series and Integrals. 1906. P. 246.

It seemed possible that the first objection might be reconciled with existing knowledge, if the exponential curve were not the only one which could fit the temperatures considered. It might well happen that another curve of the same general shape, e. g., a parabola with its axis vertical, would fit the results just as well. In fact, taking Weilenmann's figures for Berne for the month of January, we have

$$\theta = -3.79 + 0.98e^{-.17t}.$$

This is the most unfavorable case in every respect, for the value of log b is very small ($\bar{1}.925$), and the maximum value of t is large, i. e., 7. Supposing now that the right-hand side be exprest in powers of t, we have

$$\theta = -2.81 - 0.17\,t + 0.015\,t^2 - 0.0008\,t^3 + \ldots.$$

The maximum value of this last term amounts to a tenth of a degree. But it can easily be seen that this is greater than the errors that would result in using a three term formula, like

$$\theta = a_0 + a_1 t + a_2 t^2 \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

because the values of the a_0, a_1, a_2, would not be exactly the same as in the previous series, but would be altered in order to compensate for the omission of the final term. It is to be observed that equation (4) contains exactly the same number of arbitrary constants as equation (1), and that equation (4) is an expansion in Maclaurin's series. It is the natural form to be assumed for approximations to a slowly varying function. Any region which is sufficiently narrow to give good results when only the first three terms of this series are used, should give equally good results if equation (1) is used. In fact, provided the complete Maclaurin series has alternating terms which decrease in the same general way, as the exponential series, equation (1) should give better results than equation (4), but would not necessarily on that account have any real physical significance.

Still, no light was thrown on the second difficulty; the constancy of the coefficients calculated by Weilenmann. They varied widely from month to month, but the yearly average gave fairly constant results. With regard to this difficulty, it should be remarked that the constancy is not quite so great as at first appears; for, supposing that the constant b is very nearly equal to 1, a more satisfactory method is to write $b = e^{-h}$, and deal with the value h, which would be the quantity dealt with in a theoretical investigation. Going back to Table 1, the values for log b vary from $\bar{1}.934$ to $\bar{1}.942$, i. e., from -0.066 to -0.058, a variation of 13 per cent; whereas, the variation in the value of b, from 0.859 to 0.875, is less than 2 per cent. Both of these variations are probably small in comparison with the change in the average diffusivity of the earth's surface layers. The matter rested thus until a few months ago, when, by the very kind assistance of Prof. Cleveland Abbe, I was enabled to test the original evidence on which the law was based.

The first result of this examination has been to show that the exponential formula gave only slightly better results, on the whole, than the parabolic formula—as was to have been expected from the nature of the case. The details are tabulated below.

The second result, unexpected, but more important, has been to show that the value of log b varies between wider limits than those found by Weilenmann. For, as a result of recalculation, in the case of Geneva, the value of log b should be $\bar{1}.965$ instead of $\bar{1}.939$. In the case of Berne, recalculation confirmed Weilenmann's result of $\bar{1}.935$. This recalculation has been verified by the kindness of Dr. F. Maurer, of Zurich. Geneva was selected because, as may be seen from Table 1, the observations extended over a greater number of years than was the case with any other place. Berne was chosen because Weilenmann published a detailed and very convincing table giving the differences between the results as calculated and observed. Between two places so close to one another as Berne and Geneva, there is a variation in the value of

TABLE 2.—*Monthly means of temperature differences measured from midnight for Geneva (1836-1860), taken from Schweizerische Meteorologische Beobachtungen, 1872, p. xxxiv.*

Month.	5 p.m.	6 p.m.	7 p.m.	8 p.m.	9 p.m.	10 p.m.	11 p.m.	12 mid't.	1 a.m.	2 a.m.	3 a.m.	4 a.m.	5 a.m.	6 a.m.	7 a.m.
December	1.44	1.10	0.84	0.65	0.48	0.31	0.14	0	−0.08	−0.12	−0.14	−0.20	−0.30	−0.40	−0.42
January	1.70	1.30	0.99	0.74	0.55	0.37	0.18	0	−0.13	−0.20	−0.28	−0.40	−0.54	−0.68	−0.71
February	....	2.18	1.67	1.20	0.77	0.43	0.17	0	−0.13	−0.28	−0.49	−0.77	−0.99	−1.12	....
March	....	**3.42**	2.74	2.08	1.50	0.98	0.50	0	−0.54	−1.11	−1.61	−1.93	−1.96	**−1.62**	....
April	....	....	**3.01**	2.28	1.65	1.12	0.59	0	−0.68	−1.36	−1.89	−2.09	**−1.85**	....	....
May	....	....	....	**2.40**	1.69	1.10	0.57	0	−0.63	−1.22	−1.64	**−1.70**	....	....	....
June	....	....	....	**3.42**	2.49	1.64	0.82	0	−0.78	−1.40	−1 68	**−1.50**	....	....	....
July	....	....	**4.54**	3.47	2.49	1.63	0.83	0	−0.86	−1.65	−2.16	−2.20	**−1.64**	....	....
August	....	....	**3.79**	2.75	1.92	1.28	0.69	0	−0.86	−1.77	−2.49	−2.72	**−2.32**	....	....
September	....	....	**3.06**	2.16	1.46	0.94	0.50	0	−0.64	−1.37	−2.01	−2.33	−2.16	....	....
October	....	**2.49**	**1.81**	1.24	0.82	0.52	0.27	0	−0.34	−0.72	−1.10	−1.34	−1.36	−1.09	....
November	**1.99**	1.58	1.25	0.98	0.72	0.47	0.22	0	−0.18	−0.31	−0.42	−0.52	−0.59	−0.60	**−0.45**
Means	....	....	....	1.95	1.38	0.90	0.46	0	−0.49	−0.96	−1.33	−1.48	....	....	....

The figures in bold face type are obviously influenced by the sun's heat.

TABLE 3.—*Errors in calculated temperatures, using Weilenmann's values for the constants in the formula, $t = C(b^z - 1)$, Geneva (1836-1860), p. xxxiv, xxxv.*

Month.	5 p.m.	6 p.m.	7 p.m.	8 p.m.	9 p.m.	10 p.m.	11 p.m.	12 mid't	1 a.m.	2 a.m.	3 a.m.	4 a.m.	5 a.m.	6 a.m.	7 a.m.	C.	−log b.
December	−0.02	−0.01	−0.01	−0.06	−0.07	−0.07	−0.03	0	−0.01	−0.05	−0.10	−0.10	−0.14	0.02	0.00	0.59	0.076
January	0.00	0.05	0.06	0.04	0.00	−0.03	−0.02	0	−0.02	−0.07	−0.10	−0.08	−0.02	0.03	0.00	1.22	0.054
February	....	−0.02	0.03	0.08	0.13	0.13	0.11	0	−0.11	−0.17	−0.15	−0.05	0.01	0.01	....	2.30	0.048
March	....	**0.15**	−0.09	−0.10	−0.11	−0.11	−0.09	0	0.18	0.57	0.65	0.72	0.53	**0.00**	....	3.08	0.054
April	....	....	0.56	0.39	0.23	0.05	−0.04	0	0.19	0.44	0.59	0.45	**−0.09**	....	....	4.25	0.053
May	....	....	....	**0.04**	0.06	0.01	−0.04	0	0.14	0.28	0.29	**−0.02**	....	....	....	5.83	0.048
June	....	....	....	−0.98	−0.74	−0.53	−0.29	0	0.29	0.46	0.23	−0.22	....	....	....	2.67	0.089
July	....	....	**0.14**	0.05	0.00	−0.07	−0.10	0	0.20	0.41	0.40	−0.02	**−1.00**	....	....	6.02	0.050
August	....	....	**0.89**	0.77	0.57	0.28	0.04	0	0.20	0.53	0.73	0.50	**−0.32**	....	....	5.90	0.043
September	....	....	**0.72**	0.71	0.58	0.35	0.11	0	0.09	0.31	0.50	0.41	**−0.14**	....	....	2.24	0.074
October	....	**0.01**	0.12	0.19	0.18	0.10	0.01	0	0.09	0.25	0.44	0.52	0.89	**0.00**	....	1.94	0.060
November	**−0.01**	−0.10	−0.16	−0.21	−0.20	−0.15	−0.08	0	0.07	0.11	0.14	0.19	0.20	0.18	**0.00**	0.58	0.092
Arithmetic mean	....	....	....	0.30	0.24	0.16	0.08	0	0.13	0.30	0.36	0.27	....	....	....	....	0.061
Algebraic mean	....	....	....	0.07	0.05	0.00	−0.03	0	0.11	0.26	0.30	0.19	....	....	....	....	....

TABLE 4.—*Errors in temperatures recalculated with new constants for the formula $t = C(b^z - 1)$, Geneva (1836–1860).*

Month.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid't	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	C.	—log *b*.
December	—0.02	—0.01	—0.01	—0.06	—0.07	—0.07	—0.03	0	—0.01	—0.05	—0.10	—0.10	—0.14	0.02	0.00	0.59	0.076
January	0.00	0.05	0.06	0.04	0.00	—0.03	—0.02	0	—0.02	—0.07	—0.10	—0.08	—0.02	0.03	0.00	1.22	0.054
February	....	—0.02	0.03	0.08	0.13	0.13	0.11	0	—0.11	—0.17	—0.15	—0.05	0.01	0.01	....	2.30	0.048
March	....	—0.02	0.01	0.03	0.03	0.00	—0.02	0	0.09	0.25	0.36	0.32	0.00	—0.65	....	6.89	0.029
April	....	....	—0.10	0.01	0.05	0.00	—0.04	0	0.14	0.29	0.30	—0.01	—0.76	....	....	25.1	0.0095
May	....	....	....	—0.11	0.02	0.03	0.00	0	0.07	0.11	—0.02	—0.50	....	....	....	55.4	0.0044
June	....	....	....	0.14	0.00	—0.09	—0.10	0	0.15	0.21	0.00	—0.60	....	....	....	5.16	0.057
July	....	....	0.08	0.00	—0.04	—0.09	—0.10	0	0.21	0.42	0.42	0.00	—0.97	....	....	6.01	0.495
August	....	....	—0.34	0.00	0.14	0.09	0.00	0	0.18	0.41	0.45	0.00	—1.07	....	....	250.0	0.00144
September	....	....	—0.39	—0.01	0.17	0.16	0.05	0	0.07	0.23	0.28	0.01	—0.77	....	....	—29.6	—.0082
October	....	—0.67	—0.28	0.00	0.12	0.11	0.05	0	0.02	0.07	0.11	0.01	—0.32	—0.95	....	—16.6	—.0084
November	—0.08	0.04	—0.01	—0.06	—0.08	—0.08	—0.04	0	0.02	0.02	0.01	0.02	0.00	—0.06	—0.28	1.12	0.065
Arithmetic mean	....	....	....	0.03	0.07	0.07	0.05	0	0.09	0.19	0.19	0.06	....	....	....	....	0.035
Algebraic mean	....	....	....	0.00	0.04	0.01	—0.01	0	—0.07	0.14	0.13	0.015	....	....	....	....	....

TABLE 5—*Errors in temperatures calculated by the formula $t = -a_1 z + a_2 z^2$, Geneva (1836–1860).*

Month.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid't	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	a_1.	a_2.
December	—0.07	0.01	0.04	0.01	—0.01	—0.02	0.00	0	—0.04	—0.09	—0.15	—0.14	—0.08	0.01	0.03	0.125	0.010
January	—0.10	0.01	0.06	0.06	0.03	0.00	—0.01	0	—0.03	—0.09	—0.13	—0.12	—0.06	0.01	0.00	0.157	0.009
February	....	—0.07	0.02	0.10	0.16	0.16	0.09	0	—0.12	—0.20	—0.19	—0.08	0.00	0.02	....	0.268	0.014
March	....	—0.04	0.00	0.05	0.05	0.02	—0.01	0	0.09	0.23	0.34	0.30	0.00	—0.64	....	0.470	0.0156
April	....	....	—0.28	0.00	0.04	0.00	—0.04	0	0.14	0.29	0.31	00.0	—0.73	....	....	0.546	0.006
May	....	....	....	—0.13	0.00	0.02	—0.01	0	0.10	0.12	0.00	—0.47	....	....	....	0.555	0.003
June	....	....	....	0.08	0.00	—0.07	—0.08	0	0.13	0.19	0.00	—0.56	....	....	....	0.695	0.045
July	....	....	0.01	0.01	0.00	—0.05	—0.08	0	0.19	0.39	0.39	0.00	—0.91	....	....	0.721	0.043
August	....	....	—0.34	0.00	0.14	0.09	0.00	0	0.18	0.41	0.45	0.00	—1.07	....	....	0.684	0.001
September	....	....	—0.38	0.00	0.18	0.16	0.06	0	0.07	0.23	0.28	0.01	—0.77	....	....	0.561	—0.005
October	....	—0.45	—0.27	0.00	0.12	0.11	0.05	0	0.01	0.06	0.10	0.00	—0.33	—0.74	....	0.323	—0.003
November	—0.06	—0.01	0.00	—0.04	—0.05	—0.05	—0.02	0	0.01	—0.01	—0.01	—0.01	00.0	—0.04	—0.20	0.184	0.013
Arithmetic mean	....	....	....	0.03	0.065	0.06	0.04	0	0.09	0.19	0.20	0.055	....	....	....	....	....
Algebraic mean	....	....	....	0.02	0.055	0.03	—0.00	0	0.06	0.13	0.12	—0.00	....	....	....	....	....

TABLE 6.—*Geneva (1836–1860).*

Mean values taken from previous tables.

Table.	8 p. m.	9 p. m.	10 p. m	11 p. m.	12 mid.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	—log *b*.
Table 2	1.95	1.38	0.90	0.46	0	—0.49	—0.96	—1.33	—1.48	....
Table 3	0.07	0.05	0.00	—0.03	0	0.11	0.26	0.30	0.19	0.061
Table 4	0.00	0.04	0.01	—0.01	0	—0.07	0.14	0.13	0.015	0.035
Table 5	0.02	0.055	0.03	—0.00	0	0.06	0.13	0.12	—0.00	....
The means of the errors, irrespective of sign.										
Table 3	0.30	0.24	0.16	0.08	0	0.13	0.30	0.36	0.27	0.061
Table 4	0.03	0.07	0.07	0.05	0	0.09	0.19	0.19	0.06	0.035
Table 5	0.03	0.065	0.06	0.04	0	0.09	0.19	0.20	0.055	....

log *b* from —0.065 to —0.035, a variation of 60 per cent of the mean value.

The final conclusion which I wish to draw is that, on theoretical grounds, the exponential is an inconvenient means of expressing the rate of nocturnal cooling. It would seem to be a wiser plan to take the nocturnal temperatures along with the diurnal temperatures, and study both together in the usual manner, by calculating the first few terms in the Fourier series which can be found to represent them.

The details of these calculations may be found in Tables 2–6. The latter sums up the results of the previous tables.

EARLY METEOROLOGICAL DATA FOR SALINE, MICH.[1]

By J. E. BUCHANAN. Dated Cambridge, Mass., May 12, 1908.

There is a certain interest in considering for the first time any old weather records from any portion of the United States, providing they be reliable. This interest is greatly increast if the records come from a locality for which no earlier observations exist.

Last December Prof. Cleveland Abbe received a letter from Mr. George R. Marvin, of Boston, Mass., concerning some old weather records for Saline, Mich., and referred this letter to Prof. R. DeC. Ward, of the Department of Geology and Geography of Harvard University. These observations are the subject of this paper.

The records to which Mr. Marvin referred were kept in the form of a diary by his great-grandfather, Mr. Thomas Pope. In order to understand why Mr. Pope kept such a careful diary, some salient points of his life need to be noted. He was born at New Bedford, Mass., and spent his early life in the New England States. He was graduated from Harvard in 1833, and no doubt acquired a scientific turn of mind while in college. In 1838 he moved to Saline, Mich., near which place he bought a farm, and began farming in a very scientific way for those days. Indications of his scientific methods in farming are seen from his diary, in which he recorded not only weather conditions but all details of farm life. The record of the early years is lost, but we have that portion of the diary which covers the period from September, 1847, to September, 1854.

The record consists mainly of temperature data. Mr. Pope took the temperature three times daily, and there is no record missing in the seven years. He also recorded the first frost, the date when the frost was out of the ground in the spring, the time of planting and harvesting of different crops, and other farm data, only parts of which are tabulated in this article.

Such records are of little value unless taken under proper conditions. To ascertain these conditions, Mr. Pope's daughter, Mrs. E. S. Ritchie, of Cambridge, Mass.; his daughter-in-law, Mrs. W. E. Pope, of Saline, Mich., and his son, Dr. F. H. Pope, of Bothwell, Canada, were consulted personally, or by letter. They agreed as to the manner of taking the temperature, the location of the thermometer, and the other conditions necessary to prove the reliability of the records.

Mr. Pope made readings three times daily, at 6 a. m., 12 m., 6 p. m., local time, not deviating from this time either summer or winter. If Mr. Pope was absent at any time, some one was

[1] A partial report made in the course in advanced climatology given under the direction of Prof. R. DeC. Ward, of Harvard University, 1907–8.